Plankton & the Antarctic Ecosystem

What are plankton? Are all plankton the same?

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PLANTON & THE ANTARCTIC ECOSYSTEM

Palmer Station Long Term Ecological Research program (PAL LTER) investigates the marine ecosystem of the western Antarctic Peninsula (WAP). The location is distinctive with a north-south geographic orientation exposing it to extreme weather and complex ocean circulation patterns.

Contributing to the uniqueness of the area are landforms and interconnected systems including an immediate coastal region (0 – 300m deep), a continental shelf region (300 – 1,000m deep) and a continental slope region (> 1,000 m deep).

On an annual basis, between the months of October and April (the Antarctic summer), LTER scientists head to Palmer station, one of three U.S. Antarctic coastal research stations. Efforts are complemented by semiweekly ship-based hydrographic studies in January along the western Antarctic peninsula coastline. PAL LTER scientists have explored this region since 1990 using a sampling grid to monitor the ocean at equal intervals year after year as well as document how the ecosystem is changing over time. Along the grid the sampling stations are approximately 100 km apart (north to south) and 20km across the continental shelf (See figure 1). Ship-board procedures include measuring the physical conditions, the water boundaries, the flow and characteristics of the water and its structure, its circulation and its productivity.

Since Palmer LTER began back in 1990, the greatest impacts in this region are climate change, sea ice duration, and seasonal inputs from glacial melt water. The peninsula is warming by ~ 7°C over the past 50 years and this is decreasing the duration of sea ice by almost 100 days since 1978 (Ducklow et al. 2013).

Documenting these seasonal changes, sampling the core properties of water masses, understanding what nutrients are available and how they are geographically distributed is critical. Additionally, scientists must also take into account the influence of wind and atmospheric patterns on ocean circulation. Uncovering what's hidden and identifying patterns in the data help scientists track the ecosystem. New patterns appear, trends are documented and scientists forecast change over time.

Considering many organisms’ life cycles are tightly linked to these seasonal changes, scientists continually try to pinpoint what drives the changes and how they impact the ecosystems’ productivity. To truly understand living systems involves looking at how energy flows through it, starting from simple green plants up to top apex predators. Since phytoplankton (algae) fuel the transfer of energy to consumers in food webs; they are a good place to investigate these complex connections. Plankton are highly sensitive indicators of environmental change and often reveal essential information to scientists on the ecological health of the ocean. In fact, their abundance, the timing of their blooms and their species often expose how a marine ecosystem is surviving at a particular place and time.

Figure 1: A map of the LTER Grid along the western Antarctic Peninsula (WAP). The small yellow dots are regular hydrographic stations. Red dots show locations of Palmer Station, Rothera (UK) station and Charcot Island.
Plankton & the Antarctic Ecosystem

What are Plankton?
Plankton (derived from the Greek word plaktos) drift in the ocean, alone or in colonies. They play a role in the complex marine food web and move at the mercy of the ocean’s currents since they lack the power to swim against them. They can be categorized by their size which range from micrometers to meters. By comparison, a grain of salt is about 1 millimeter which is a 1,000 times larger than a micrometer. The largest plankton can be several meters long, but most are barely visible to the naked eye. Along with categorizing them by size, scientists also distinguish plankton by their type, shape, color and their function.

Phytoplankton are primary producers, autotrophic algae that depend on sunlight, water, carbon dioxide and nutrients to help make their own food. Their distribution in the ocean is dependent on the intensity of light, the time of day, salinity, temperature, currents, tides, nutrients and seasonal cycles. Phytoplankton play a critical role in the ocean producing nearly half of the world’s oxygen while the carbon dioxide they convert into organic carbon helps to regulate the planet’s climate. Phytoplankton form the base of nearly all ocean food webs.

Phytoplankton’s small size is an adaptation to life in the ocean because smaller cells easily absorb the diluted nutrients giving them the ability to feed off of non living (inorganic) materials. Residing near the surface, phytoplankton use sunlight in the upper 100 - 200 meters of the ocean to photosynthesize and make their own simple sugars. They are able to do this because of accessory pigments that capture the sun’s energy. These accessory pigments, like chlorophyll, produce algae that vary in color from golden browns, to hues of red and bright green.

Other plankton are animals called zooplankton. Zooplankton also vary in size from tiny, feathery plankton (microzooplankton; 2-20 um) to crustaceans such as copepods and krill (meso-zooplankton; 20-200um) to large jellyfish (macrozooplankton; 200um+). They are heterotrophs and need to feed on microscopic algae like phytoplankton. In some cases zooplankton even feed on each other for nutrition. Their physical adaptations can consist of feathery hairs (cilia) or long spines or even air filled bladders but they seem to find ways to survive and float easily. Some zooplankton are fleeting visitors as they pass through this life cycle as planktonic larvae (temporary zooplankton; i.e., fish, sea urchin, & shellfish larvae) staying near the ocean’s surface; others spend their entire lives in this microscopic drifting stage (permanent zooplankton). A lifestyle such as this has its benefits, like the dispersal of its population at a relatively low energy cost. However, this come with some challenges too; like being carried away from an area that has optimal conditions for their survival.

At the mercy of the oceans current zooplankton survival depends on their ability to catch food; and they use ingenious techniques to do it. Some create whirlpools, others like jellyfish use poison darts to sting their prey. Copepods, chaetognaths, krill, barnacle and crab larvae, salps, sea butterflies, jellyfish and fish eggs are easily recognizable and some of the most common examples of zooplankton.
The Role of Plankton

Phytoplankton not only produce oxygen ($O_2$) that fuels life on Earth but they also convert inorganic carbon dioxide ($CO_2$) into organic carbon (C), that helps regulate our planet’s climate! Scientists go to great lengths to measure plankton community changes as well as document their impact on marine ecosystems. Sometimes this includes mapping how plankton are geographically distributed over an area using global positioning satellites (GPS). Other times it includes measuring the rate at which plankton grow. These studies lead scientists to predict patterns and monitor trends over time.

In many cases, whether plankton increase or decrease they impact bottom-up forcing - an instance when primary producers or primary consumers are removed or diminished in an ecosystem triggering a change in population size of those who prey on them. If phytoplankton decrease then they can also spark an increase in atmospheric $CO_2$ levels - a regulator of our Earth’s climate. Plankton are like sentinels prompting scientists to other changes in a marine ecosystem.

Equipment to Measure Plankton

Monitoring changes over a widespread ocean ecosystem requires more than a microscope - although that is certainly necessary. Often times, large plankton nets (Figure 2) are towed off the stern of a research vessel at a specific rate of speed which keeps the volume of water passing through the net or flow rate consistent. Zooplankton animals collect in a sieve-like cup at the end of the net, are hauled onto the deck of the ship, then brought to the ships laboratory to be identified. The species and quantity of plankton are documented, sometimes using a microscope and other times just the naked eye. Check out how the 2M zooplankton net works from the ship and how plankton are sampled from Palmer station here.

To complement ship-based net tows, Palmer LTER scientists also use a variety of other instruments to sample the region. Many are equipped with various sensors to capture the physical properties of the water like chlorophyll concentrations, conductivity, temperature, depth and salinity. A CTD is one instrument shaped like a carousel (or rosette) with a dozen bottles circling its frame (Figure 3). It is lowered down to the ocean seafloor. As it rises to the surface, it is programmed to collect water samples at different depth intervals. Information from the CTD is parlayed in real time to a computer on the ship. Other data is obtained from filtering the bottled water samples from around the carousel once it is back on deck.

To study plankton scientists also use robotic, autonomous, underwater vehicles or AUVs. The AUVs are programmed via a global positioning system and swim in a saw-toothed pattern between target points from the ocean’s surface down to ~ 100m depth. The data obtained from AUVs is uploaded from the tail of the glider as it surfaces during flights and then posted to the intranet in “real-time”. AUVs provide the research ship an opportunity to adapt or modify its sampling strategies to handle the most recent characteristics in the water column. Learn more about how AUVs are used during Palmer LTER polar research cruises.

As scientists track the amount of phytoplankton in the ocean over large regions they often use satellite imagery too. To us, the ocean may simply appear blue or possibly blue green in color; however, small variations in colors actually reveal the presence or absence of different amounts of pigment or chlorophyll $a$ in phytoplankton. Differing concentrations of phytoplankton can subtly change the color of the ocean. Satellites detect these changes in color and create stunning images of the chlorophyll concentrations on the Earth’s ocean surface. One such satellite is the Sea-viewing Wide Field-of-View Sensor (SeaWiFS), designed to measure changes in ocean color signifying chlorophyll concentrations and seasonal changes in the distribution of phytoplankton.
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Target Audience: Grades 6 - 9 Biology, Marine Science, or Environmental Science.
Time: 60 - 80 minutes
Next Generation Science Standards: Students who demonstrate understanding can:

MSLS2-1 — Analyze and interpret data to provide evidence for the effects of resource availability on organisms and populations of organisms in an ecosystem. Emphasis on cause/effect relationships between resources and growth of organisms.
MS-LS2-2 - Construct an explanation that predicts patterns of interactions among organisms across multiple ecosystems. (Examples of interactions could include competitive, predatory and mutually beneficial).

Climate Literacy Principles
EP2 Climate if regulated by complex interactions among components of the Earth system
   2f Equilibrium and feedback loops in climate systems
EP 3 Life on Earth Depends on, is shaped by and affects climate
   3a Climate's role in habitats ranges and adaptations of species to climate changes
EP 4 Climate varies over space and time through both natural and man-made processes

Materials:
Plankton net  Petri dish  Dissecting microscope
Plankton samples  Pipette  Glass slides with well
Compound microscope  Identification sheet  Plankton data collection sheet

Vocabulary
Abundance: The number of a particular type of organism within a specific community.
Autotroph: ability to make their own food
Biodiversity: The diversity, or variety living things in a particular area or region.
Biomass: the amount of organisms in a given area or habitat.
Bottom Up Forcing: when primary producers or primary consumers are removed or diminished in an ecosystem triggering a change in population size of those who prey on them.
Chlorophyll: A pigment that all plants contain which allows them to perform photosynthesis. One type of chlorophyll, chlorophyll a naturally green photosynthetic pigment can be directly measured and is used as the primary indicator of algal biomass.
Diatom: Single-celled algae that are aquatic and produce a hard outer covering made of silica.
Dinoflagellate: A large group of unicellular, photosynthetic micro plankton. A vast majority (90%) are found in marine environments. Some species of dinoflagellates are toxic and are responsible for red tides.
Heterotroph: feed on plants for nutritional needs.
Larval Stage: The juvenile form of an animal that often looks very different from the adult. In marine animals, larva are typically free-floating or planktonic and change form as they grow.
Phytoplankton: Microscopic algae that live in the water and produce their own food through photosynthesis. Collectively, phytoplankton are the foundation of the marine food web.
Photosynthesis; Chemical process by which plants convert light energy into chemical energy (glucose) $6\text{CO}_2 + 6\text{H}_2\text{O} + \text{light energy} \rightarrow \text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_2$
Primary Productivity: The amount of material (biomass) produced by plants (primary producers) through the process of photosynthesis.
Zooplankton: Drifting marine animals, like invertebrates or larval fishes that inhabit the oceans of the world and graze on phytoplankton.
**Plankton & the Antarctic Ecosystem**

*What are plankton? Are all plankton the same?*

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**Objective(s):**
- To identify common types of marine plankton (phytoplankton and zooplankton).
- Analyze and interpret data using satellite images
- Understand that changes in patterns, biodiversity and abundance of plankton impact interactions among organisms
- Plankton populations are used as measures of health in an ecosystem.

**Procedure:**

*Teacher notes: Plan ahead to order / collect plankton sample(s). Have both compound and dissecting microscopes ready at lab stations around the classroom. Assign students to read the first three pages of background information ahead of time or for homework the night before this lab. Prior to student observations, review how to carefully use each of the different microscopes.*

1. Take a moment to watch the video clips of plankton samples being collected both at Palmer station and on the research vessel the **Lawrence M Gould**. You can find them here: [http://pal.lternet.edu/education/k-12/instructional-materials-resources](http://pal.lternet.edu/education/k-12/instructional-materials-resources). The clips will acquaint you with the deployment of the 2 meter zooplankton net and phytoplankton sampling procedures from Palmer station.

2. Begin the lab portion by using a medium pipette to remove a small sample of the sea water.

3. Place one drop of sea water into the well of a glass slide and the remaining water into a petri dish.

4. Place the glass slide beneath the compound microscope lens adjusting the lens to low power. Adjust the focus until you see the organisms.

5. Remove the slide and set aside. Now place the petri dish under the dissecting scope. Use this microscope to observe any larger planktonic organisms.

6. Throughout your observations use the attached data collection sheets, and choose at least six different types of plankton to sketch with as much detail as possible. Using the **Plankton Identification** sheets attached to this lab to identify your plankton and label as either phytoplankton or zooplankton.

7. You can work in small groups to answer the analysis questions.

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Student Data Collection Sheet: Accurately draw six different types of plankton species on this data sheet, placing one in each circle. Please record what power you are using on the microscope, what kind of microscope aided you in your observation and identify the type of plankton you saw (use the Plankton Reference Guide as a resource).

Water Sample Location: ____________________________ Date Sample Collected: _____________
Time Sample was Collected: Morning    Afternoon    Evening    (Biological Supply Company)

Power ______________________  Power ______________________  Power ______________________
Plankton Identification: ____________________  Plankton Identification: ____________________  Plankton Identification: ____________________
Phytoplankton or Zooplankton          Phytoplankton or Zooplankton          Phytoplankton or Zooplankton

Power ______________________  Power ______________________  Power ______________________
Plankton Identification: ____________________  Plankton Identification: ____________________  Plankton Identification: ____________________
Phytoplankton or Zooplankton          Phytoplankton or Zooplankton          Phytoplankton or Zooplankton
1. Explain at least three methods that Palmer LTER scientists use in collecting and monitoring plankton along the western Antarctic peninsula.

2. Of the plankton you observed, identify and list at least two differences between your phytoplankton sketches and your zooplankton sketches.

3. Looking at your sketches, which type of plankton have appendages (legs, arms or antennae) phytoplankton or zooplankton? What function do you think these appendages serve given the plankter’s size?

4. Of the plankton you sketched, which ones did not have appendages, phytoplankton or zooplankton? How do these plankton move in the ocean if they don’t have appendages?

5. Which were larger and easier to observe - phytoplankton or zooplankton?

6. Were phytoplankton or zooplankton more abundant in your sample?

7. Identify and list what scientists measure over long periods to document seasonal changes in plankton? Choose one and explain the cause/effect relationship on plankton growth and/or decline. (i.e. decreasing cloud cover impacts light intensity -> plankton photosynthesize less at the surface)

8. Did your plankton sample seem to have many similar species or many different species? What does plankton biodiversity tell us about the interactions among organisms in a food web?
Plankton Reference Sheet

**PHYTOPLANKTON**

<table>
<thead>
<tr>
<th>DINOFLAGELLATES</th>
<th>DIATOMS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ceratium</td>
<td>Choaeoceros</td>
</tr>
<tr>
<td>Noctiluca</td>
<td>Asterolonella</td>
</tr>
<tr>
<td>Peridinium</td>
<td>Licmophora (epibiotic diatom)</td>
</tr>
<tr>
<td>Gonyaulux</td>
<td>Pseudonitzschia</td>
</tr>
<tr>
<td>Protoperidinium</td>
<td>Nitzschia</td>
</tr>
<tr>
<td>Alexandrium</td>
<td>Coscinodiscus</td>
</tr>
</tbody>
</table>

**ZOOPLANKTON**

<table>
<thead>
<tr>
<th>PERMANENT</th>
<th>TEMPORARY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ciliate (unidentified)</td>
<td>Sea star larva</td>
</tr>
<tr>
<td>Tintinnid</td>
<td>Bivalve larva</td>
</tr>
<tr>
<td>Rotifer</td>
<td>Bryozoa larva</td>
</tr>
<tr>
<td>Radiolarians</td>
<td></td>
</tr>
<tr>
<td>Salp (doliolum)</td>
<td>Polychaete worm</td>
</tr>
<tr>
<td>Larvacean (oikopleura)</td>
<td>Snail veliger larva</td>
</tr>
<tr>
<td>Ctenophore</td>
<td>Barnacle nauplius larva</td>
</tr>
<tr>
<td>Flatworm</td>
<td>Barnacle cypris larva</td>
</tr>
<tr>
<td>Chaetognath (arrow worm)</td>
<td>Crustacean nauplius larva</td>
</tr>
<tr>
<td>Jelly medusa</td>
<td>Crab megalops larva</td>
</tr>
<tr>
<td>Isopod</td>
<td>Crab zoea larva</td>
</tr>
<tr>
<td>Cladocera (male)</td>
<td>Fish egg</td>
</tr>
<tr>
<td>Cladocera (female with eggs)</td>
<td></td>
</tr>
<tr>
<td>Mysis shrimp</td>
<td></td>
</tr>
<tr>
<td>Amphipod</td>
<td></td>
</tr>
<tr>
<td>Copepod</td>
<td></td>
</tr>
<tr>
<td>Copepod larva</td>
<td></td>
</tr>
<tr>
<td>Ostracod</td>
<td></td>
</tr>
</tbody>
</table>

**Taking it Further (Teachers: this may be used as a form of assessment or an extension to the activity)**

Plankton play an important role in the structure of the ocean. Scientists like assistant research professor Grace Saba from Rutgers University work with Palmer LTER and go to great lengths to track the amount of phytoplankton in the ocean over large spatial areas. Grace often uses satellite imagery which captures the presence or absence of different amounts of pigment or **chlorophyll a** in phytoplankton from space. The chlorophyll helps her to identify concentrations of phytoplankton in the ocean as chlorophyll changes the color of the oceans’ surface.

Below are three SeaWiFS satellite time series images (1997 - 2010) from the Palmer peninsula region. The images are monthly 1kilometer-resolution averages for the months of December through February. Compare the three different months and explain your findings using supporting background information.

![Chlorophyll Concentration](image)

**Answer:**

[Blank space for answer]

[Image of three satellite images showing chlorophyll concentration for December, January, and February]
Scientific Publications

Phytoplankton Identification Books:

Educational Books:

Online Phytoplankton Resources:
1. Palmer LTER Outreach Materials http://pal.lternet.edu/education
Plankton and Palmer LTER research:  Note: This information if provided to assist educators in guiding students during their plankton analysis and help them connect this lab to the research of the Palmer LTER.

Along the western Antarctic Peninsula sea ice affects all levels of the marine ecosystem from ocean productivity and food web processes, to the timing, cycles and breeding success of krill and penguins year after year. Polar marine species life cycles are synchronized with the annual timing of sea ice. The last 35 years of satellite observations have revealed that sea ice duration has actually become ~ 100 days shorter (Stammerjohn et al. 2013), and this is due to the rapid winter warming in the WAP region (Vaughan et al. 2003). This shorter cycle of sea ice leaves larger areas of the ocean ice-free in the Antarctic summer season. This open ocean surface water warms as it absorbs the sun’s energy. This warming delays the advance of sea ice into the fall season, as ice cannot form as quickly on the warmer surface waters (Vaughan et. al., 2003).

Frequent high winds in the region are contributing to upwelling events where nutrient rich water from the deep reaches the surface and fuels primary production. Sea ice and glacial meltwater also contain nutrients for the phytoplankton to utilize, specifically the very important trace metal, iron. The sun’s energy also plays a role in driving the primary production throughout the water column. It prompts a process called photosynthesis, a routine by which plants (phytoplankton) make food. The sun’s energy warms the surface water, making it less dense, and the oceans’ water column becomes layered or stratified. This stratification keeps phytoplankton in the upper water column where there is plenty of light, allowing them to bloom more readily. The success at which this occurs in the WAP does however depend on the region. To study this more closely, scientists look at the relationships between nearshore systems or regions in comparison to off shore systems. They often utilize satellites to measure large regional differences in primary productivity, specifically analyzing the changes in chlorophyll-a (chl-a) concentrations. Chl-a is a pigment that allows plants/algae to make food and is represented by color variations on the oceans surface.

What scientists are finding in the WAPs shelf-slope system is that it has different characteristics in the water compared to the open pelagic areas of the ocean. In fact, nearshore quantities of chl-a pigments from the images are revealing roughly four times (4x) higher chl-a than off shore areas. Some of these changes are from seasonal summer warming when glacial meltwater runs off into the region. This meltwater lowers surface water salinity causing an increase in the frequency and abundance of certain phytoplankton groups.

Furthermore, as inshore and offshore communities are correlated, scientists are seeing north-south regional differences as well. Scientists have found that primary productivity has increased in the southern region of the WAP, although it has declined in the northern WAP region by up to 90% (Ducklow et al., 2013). Further analysis of these findings reveals a change in phytoplankton composition from large-celled diatoms (a preferred food of Antarctic krill) to now much smaller cryptophytes (or single celled photosynthetic) algae (Montes-Hugo et al. 2008, 2009).

Many of the regional studies near Palmer station are also complemented by the collection of the physical characteristics of the water column, data often times provided by the use of autonomous underwater vehicles (AUV) or gliders. Gliders have revealed that warm, deep nutrient-rich water is often being uplifted right along the slopes of underwater canyons. These areas, known as ‘hot spots’, are locations associated with enhanced concentrations of phytoplankton (chl-a). Upon further investigation, many of the water property measurements made by the gliders also reveal that phytoplankton at canyon edges are some of the healthiest in the region. As global warming reduces surface water salinity around the peninsula as a result of glacial meltwater runoff, this increases the frequency and abundance of certain phytoplankton groups, such as cryptophytes.

When scientists step back and create a model of the major players in a food web in the WAP region they begin to visualize how all these changes in phytoplankton will impact individual food chains. The long term studies from Palmer LTER scientists reveal that the northern region of the WAP is in transition from a classic short, efficient polar food chain, dominated by larger phytoplankton and zooplankton toward a more microbial food web dominated by smaller phytoplankton and bacteria (Garzio & Steinberg 2013; see also Sevrine Sailley). Despite the long-term loss of the larger diatoms preferred by krill, much of the long-term data indicates a cyclical pattern where krill (Euphausia superba) are still in abundance in the northern WAP, with large positive recruitment events every ~5 years, but with no apparent long-term change in the northern or southern WAP (Steinberg et al.).
Scientific Connections Continued...
Understanding the mechanisms by which climate variability affects multiple trophic levels in food webs is essential for determining ecosystem responses to climate change. A recent study by Saba et al. (2014) used over two decades of data collected by PAL-LTER to determine how large-scale climate and local physical forcing affect phytoplankton, zooplankton, and Adélie penguins along the West Antarctic Peninsula (WAP). They showed that positive inconsistencies in chl-a at Palmer Station occurred every 4-6 years and were constrained by physical processes from preceding winter/spring and a negative pressure difference between Antarctica and the mid-latitudes that affects winds in the WAP region. Favorable conditions for phytoplankton, specifically diatoms, included increased winter ice extent and duration, reduced spring/summer winds, and increased water column stability/stratification from enhanced salinity-driven density gradients. Years of positive chl-a anomalies were associated with the initiation of a robust krill cohort the following summer, which was evident in Adélie penguin diets, thus demonstrating that the two were tightly linked. Projected climate change in this region may have a significant, negative impact on phytoplankton biomass, krill recruitment, and upper trophic level predators in this coastal Antarctic ecosystem.

Much of the food web dynamics are still poorly studied in the Southern Ocean. What is understood however, is that many of the long term changes and the regional differences will impact community structure as well as the cycling of the oceans nutrients. Phytoplankton and those who graze on them (zooplankton) will eventually be impacted as the food web is becoming restructured. Where krill and pteropods dominate the south, salps are now dominating the north (Bernard et al. 2012). The Palmer Long Term Ecological Research (PAL) program continues to seek a comprehensive understanding of the Antarctic seasonal sea ice-influenced ecosystem as the region becomes transformed.